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<p>(21) International Application Number: PCT/US98/06970</p> <p>(22) International Filing Date: 7 April 1998 (07.04.98)</p> <p>(30) Priority Data: 08/842,928 9 April 1997 (09.04.97) US</p> <p>(71) Applicant (for all designated States except US): RHODIA INC. [US/US]; 2569 Prospect Plains Road, Cranbury, NJ 08512-7500 (US).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only): TRACY, David, James [US/US]; 37-03 Ravens Crest Drive, Plainsboro, NJ 08536 (US). LI, Ruoxin [US/US]; 1415 Ravens Crest Drive, Plainsboro, NJ 08536 (US). YANG, Jiang [CN/US]; Apartment L-8, 440 Dutch Neck Road, Hightstown, NJ 08520 (US).</p> <p>(74) Agents: SHEDDEN, John, A. et al.; Rhodia Inc., 259 Prospect Plains Road, Cranbury, NJ 08512-7500 (US).</p>	<p>(81) Designated States: AL, AM, AT, AU, J, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, P, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, Z, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, S, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, R, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, K, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b> With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</p>	
<p>(54) Title: NONIONIC GEMINI SURFACTANTS HAVING HYDROPHILIC SUGAR GROUPS</p> <div style="text-align: center; margin: 20px 0;"> <math display="block">  \begin{array}{c}  R-N-Y \\    \\  X \\    \\  R_1-N-Y_1  \end{array}  \quad (I)  </math> </div> <p>(57) Abstract</p> <p>Sugar-derived gemini surfactants contain two disaccharide moieties as the hydrophilic groups that are linked by a bridge. The compounds have general structure (I), wherein R and R<sub>1</sub> are the same or different linear, branched, saturated, or unsaturated hydrocarbyl moieties with a carbon chain length of from about C<sub>6</sub>-C<sub>23</sub> and Y and Y<sub>1</sub> are the same or different alcohol-containing moieties having at least two and preferably more hydroxyl containing groups such as glucose, fructose, lactose, and the like, and one but not both may be hydrogen, and X is a R<sub>2</sub> or -COR<sub>2</sub>CO- wherein R<sub>2</sub> is a C<sub>1</sub> to C<sub>20</sub> straight or branched chain alkyl, aryl, alkylaryl, dicarboxyaryl, or diaminoalkyl.</p>		

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**NONIONIC GEMINI SURFACTANTS HAVING HYDROPHILIC SUGAR GROUPS**

This invention relates to a novel group of nonionic surfactants having at least two hydrophobic moieties and at least two hydrophilic sugar groups per molecule useful as emulsifiers, detergents, dispersants, hydrotropes, wetting agents, corrosion inhibitors and solubilizing agents.

**BACKGROUND OF THE INVENTION**

Surfactants are well known materials which can be generally described as having a hydrophobic moiety and a hydrophilic group per molecule. A wide variety of these materials are known and are classified as anionic, cationic, nonionic and amphoteric. They are well known to have numerous uses such as emulsifiers, detergents, dispersants and solubilizing agents in the field of cosmetics, textile treatment, industrial and personal cleaning preparations, corrosion inhibitors and the like.

In nonionic surfactants, the surface-active portion bears no apparent ionic charge. Usually polyethoxy chains, glycerides or polyhydroxy functional, e.g. polyglucosides, constitute the hydrophile.

Surfactants generally are compounds having one hydrophilic group and one hydrophobic moiety. Recently, a group of compounds having two hydrophobic moieties and two hydrophilic groups have been introduced. These have become known as "gemini surfactants" in the literature (Chemtech, March 1993, pp 30-33), and J. American Chemical Soc., 115, 10083-10090, (1993) and

the references cited therein. Since their introduction, cationic and anionic "gemini surfactants" have been disclosed. Other surfactant compounds having two hydrophilic groups and two hydrophobic moieties have been disclosed but not referred to as gemini surfactants.

5           Sulfate, phosphate, and carboxylate surfactants are currently disclosed in the literature (See JAOCS 67, 459 (1990); JAOCS 68, 268 (1991); JAOCS 68, 539 (1991); and JAOCS 69, 626 (1992).

Sugar based gemini surfactants have been previously described in the literature.

10           U. S. Patent No. 5,534,197 to Scheibel et. al. discloses and claims gemini polyhydroxy fatty acid compounds wherein the bridging group consists of a variety of alkyl, aryl, arylalkyl and aminoalkyl compounds having from about 2 to 200 atoms, and the hydrophobic heads are comprised of the same or different alcohol containing moieties with two or more hydroxyl groups such as glylycerol. The  
15 surfactants are asserted to be useful as active agents in laundry detergents, fabric cleaners, and personal care.

U. S. Patent No. 5,403,922 to Garelli-Calvet et. al. discloses amphiphilic surfactants containing two sugar or sugar-derived head portions. These amphiphilic head portions are long chain aliphatic or branched aliphatic carbon chains. The  
20 chains are interrupted by various functional groups such as amines (-NH) and further comprise reducing glucides comprised of a linear or cyclized carbon chain. The hydrophile is on the ends of the hydrophobe, constituting bola-type surfactants. Bola surfactants are relatively ineffective.

U. S. Patent No. 5,512,699 to Conner et. al. discloses and claims poly-  
(polyhydroxy fatty acid amide) compounds that are asserted to be useful in  
laundry detergents, cleaning compositions, and personal care. Two identical long  
chain moieties containing hydroxyl groups are joined by a bridge consisting of  
5 polyethyleneimines, and polyethyleneamines with molecular weights below about  
50,000 and preferably below 10,000. The hydrophobe is connected via carbonyl  
groups. U. S. Patent No. 4,892,806 to Briggs et. al. discloses nonionic surfactants  
comprised of two R groups consisting of substituted and unsubstituted alkyls,  
cycloalkyls, aryls or H joined to two hydrophilic groups represented by the formula  
10  $-\text{CH}_2\text{NHCO}(\text{CHOH})_x\text{CH}_2\text{OH}$  by a carbon bridge. The compounds are useful in  
emulsions for photographic light sensitive materials.

EPA 0 688 781 to Adams teaches and claims nonionic surfactants  
comprised of two polysaccharide sugar moieties that are linked to the central  
bridge of the molecule by one of their carbonyl groups. The central bridge is  
15 comprised of a polyalkyleneamine unit wherein at least one of the amine nitrogen  
atoms has a hydrophobic, substituted or unsubstituted hydrocarbon group linked  
thereto. The compounds are disclosed as being useful in aqueous hydrophilic  
colloid compositions such as light sensitive photographic materials.

PCT Application No. PCT/US95/00767 to Scheibel et. al. discloses and  
20 claims a class of gemini polyether fatty acid amides in which two polyethoxy,  
polypropoxy and/or mixed polyethoxypropoxy moieties of the general formula  
 $[(\text{CH}_2)_y\text{O}]_n\text{H}$  are joined by branched or linear alkyl or aryl moieties of from 2-200  
carbon atoms. The surfactants may be combined with other nonionic and anionic  
surfactants and enzymes in soap and laundry detergent formulations.

PCT application No. PCT/US/00769 to Scheibel et. al. discloses and claims another class of polyhydroxy diamine compounds in which two "heads" consisting of reducing sugars such as glycerol, glucose, maltose, maltodextrin and the like are joined together by a unsubstituted, linear or branched alkyl, ether alkyl or amino alkyl consisting of from two to fifteen carbon atoms.

An article by Zhang et. al., J. Colloid. Interface Sci 177 419-426 (1996) discusses the effect of hydrophobic and hydrophilic chain lengths on the surface active properties of novel polysaccharide surfactants. The nonionic saccharide surfactants consist of an amide group that links a hydrophilic saccharide segment such as glucolactone, maltolactone, and dextrolactone to a hydrophobic alkyl segment such as hexylamine, octylamine and decylamine. It was shown that the size of the saccharide segment is important in determining the interfacial surface area of the molecule and hence its surface activity.

Eastoe et. al., Langmuir. 12, 2701-2705 (1996) discloses nonionic amphiphile surfactants comprised of two  $\eta$ -alkyl chains and two glucamide head groups. Surfactant purity, surfactant-water phase behavior, air-solution surface tension and small angle neutron-scattering characteristics are some of the surfactant characteristics disclosed. A second Eastoe et. al. article, L Langmuir 10, 4429-4433 (1994) discusses the properties of nonionic surfactants comprised of two C<sub>6</sub> hydrophobic chains and two glucamide head groups in the same fashion.

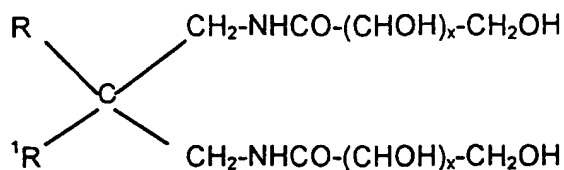
An article to Briggs et. al. J. Chem. Soc. 46, 379-380 (1995) briefly discusses the synthesis and properties of nonionic polyol surfactants derived from carbohydrate lactones. The surface properties of these nonionic gemini surfactants are rare and very few are reported in the literature.

Due to the need for new and more effective and efficient surfactants, as well as the need for mild surfactants which are biologically compatible in an ecologically sensitive environment, effort has been made to develop a new class of compounds, which demonstrate improved surface-active properties that are  
5 further characterized as mild, and environmentally benign.

Gemini surfactants contain two hydrophilic heads and two lipophilic chains linked by a small bridge. Because gemini surfactants demonstrate very special physical properties such as unusually low critical micelle concentrations (cmc) and  $\text{pC}_{20}$  values in aqueous media, they have drawn significant attention. It has been  
10 reported that ionic gemini surfactants can lower cmc values about 1000 times more efficient than single chain analogues and are about 1000 times more efficient at reducing the surface tension ( $\text{pC}_{20}$ ). Beside these outstanding physical properties, nonionic gemini surfactants can be very effective, biodegradable, and to a certain extent, available from renewable resources such as natural fats and  
15 sugars. Therefore, sugar-containing surfactants have attracted considerable attention.

The new type of sugar gemini surfactant generally contains two aliphatic long chains as lipophilic groups and two oligosaccharides as hydrophilic heads. Because sugar molecules are very water soluble, they are superior as hydrophilic  
20 heads for gemini surfactants.

Sugar gemini surfactants use various forms of sugar as hydrophilic groups such as glucose, fructose, maltose, lactose, galactose, mannose, xylose and so on. Another type of gemini surfactant contains a polyhydroxyl group as the hydrophilic head. Their general structure is shown below.



5

wherein R and R<sup>1</sup> represent a C<sub>3</sub> to C<sub>21</sub> straight or branched chain hydrocarbyl moiety. See Eastoe, and Briggs, *supra*.

Other sugar gemini surfactants have been prepared that contain two glucose hydrophilic groups and two hydrocarbon chains linked by an ethylene group. However, these bis-monosaccharide gemini surfactants were found to be insoluble in water.

10

#### DETAILED DESCRIPTION OF THE DRAWINGS

Figure 1 is the graphic results of <sup>1</sup>H-NMR and <sup>13</sup>C-NMR spectral analysis of N-decylactosylamine compound produced in example 1.

15

Figure 2 is the graphic results of <sup>1</sup>H-NMR and <sup>13</sup>C-NMR spectral analysis of the N-dodecylactosylamine compound produced in example 2.

Figure 3 is the graphic results of <sup>1</sup>H-NMR spectral analysis of the N-hexadecylactosylamine compound produced in example 3.

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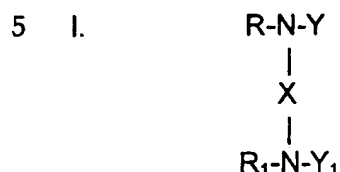
Figure 4 is the graphic results of <sup>1</sup>H-NMR and <sup>13</sup>C-NMR spectral analysis of the gemini-bis-decylactosylamide produced in example 4.

Figure 5 is the graphic results of <sup>1</sup>H-NMR and <sup>13</sup>C-NMR spectral analysis of the gemini-bis-dodecylactosylamide compound produced in example 5.5.



### SUMMARY OF THE INVENTION

Sugar-derived gemini surfactants contain two disaccharide moieties as the hydrophilic groups that are linked by a bridge. The general structure of the compounds is as follows:



wherein R and R<sub>1</sub> are the same or different linear, branched, saturated, or unsaturated hydrocarbyl moieties with a carbon chain length of from about C<sub>6</sub>-C<sub>23</sub> and Y and Y<sub>1</sub> are the same or different alcohol-containing moieties having at least two and preferably more hydroxyl containing groups such as glucose, fructose, lactose, and the like, and one but not both may be hydrogen, and X is a R<sub>2</sub> or -COR<sub>2</sub>CO- wherein R<sub>2</sub> is a C<sub>1</sub> to C<sub>20</sub> straight or branched chain alkyl, aryl, alkyl aryl, dicarboxyaryl, or diaminoalkyl.

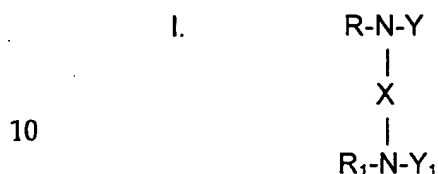
### DETAILED DESCRIPTION OF THE INVENTION

20 The general structure of the sugar-derived gemini surfactants of the present invention contain two polysaccharides as hydrophilic groups connected by a bridge. The surfactants are prepared using standard amidation, condensation and reduction reactions wherein a disaccharide such as lactose, maltose, or fructose is condensed with a terminal end amine-containing alkyl group to produce

25 a long chain molecule with the hydroxyl sugar at the hydrophilic end and the long chain aliphatic group as the lipophilic end. Two of them joined by a carbonyl-

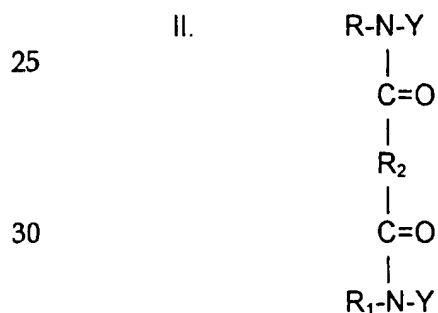
containing bridge via amidation/condensation reaction or alkylation using an alpha omega dihalide or reaction with a diisocyanate.

The novel gemini surfactants of the present invention comprise two sugar moieties as the hydrophilic group that, together with the two hydrophobic groups, are linked by a bridge. The general structure of the surfactant composition is as follows:



wherein R and R<sub>1</sub> independently represent the same or different linear or branched, saturated or unsaturated hydrocarbyl moieties with a carbon chain length of from about C<sub>6</sub> to C<sub>23</sub> and wherein Y and Y<sub>1</sub> independently represent the same or different alcohol-containing moieties having at least two and preferably more hydroxyl groups with the further stipulation that one but not both Y groups may be hydrogen and X independently represents R<sub>2</sub> or -COR<sub>2</sub>CO- wherein R<sub>2</sub> is a straight or branched chain alkyl, aryl or alkylaryl, dicarboxyaryl, or diaminoalkyl.

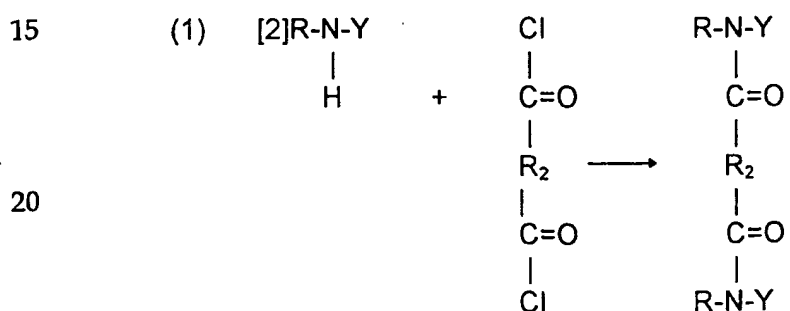
Preferably, the sugar gemini surfactants of the present invention are represented by the general formula:



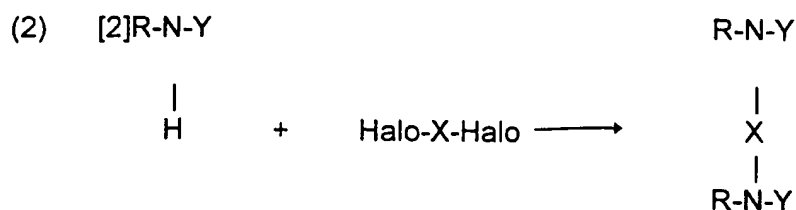
R and R<sub>1</sub> independently represent a straight or branched alkyl group of from about six (6) to twelve (20) carbon atoms. Preferably the Y moieties are selected from the group comprising monosaccharides, disaccharides, polysaccharides and the like. Suitable monosaccharides include glyceraldehyde, erythrose, threose, ribose, arabinose, xylose, lyxose, allose, altrose, glucose, fructose, mannose, gulose, idose, galactose, and talose. Disaccharides represented by Y and Y<sub>1</sub> include, but are not limited to lactose, maltose, cellobiose, sucrose, gentobiose and mixtures thereof. Suitable polysaccharides that may be represented by Y and Y<sub>1</sub> include amylose, amylopectin, trehalose and the like. Preferably, the Y groups represent a disaccharide such as lactose or maltose, and R<sub>2</sub> is aryl.

Using lactose (i.e. R=lactose) as an example, the reaction process can be schematically represented as follows:

#### SYNTHESIS SCHEMATICS



Alkyl lactosylamine is coupled by reaction with a bisacid chloride such as terephthaloyl chloride or malonic acid chloride producing the gemini surfactant.

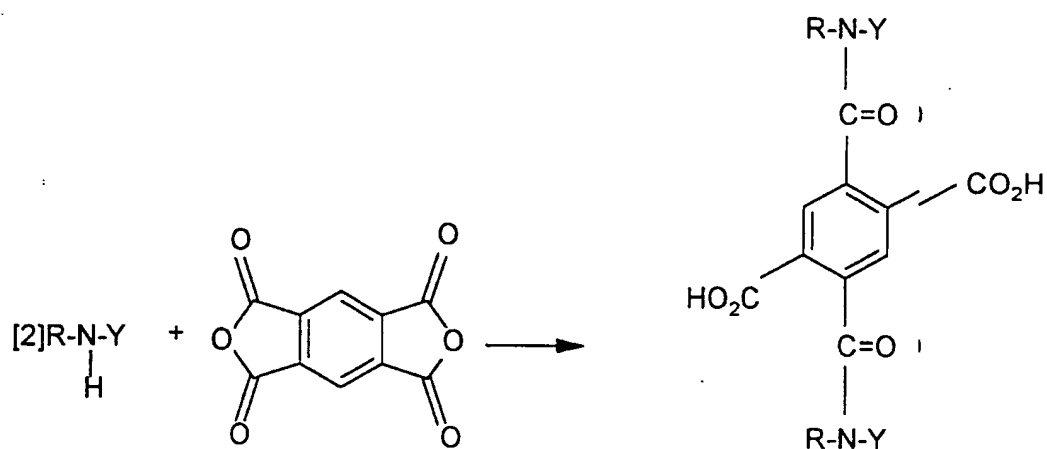


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Alkyl lactosylamine is coupled by reaction with an alpha omega halide such as xylenedihalide or 1,4 dichlorobutane producing the gemini surfactant.

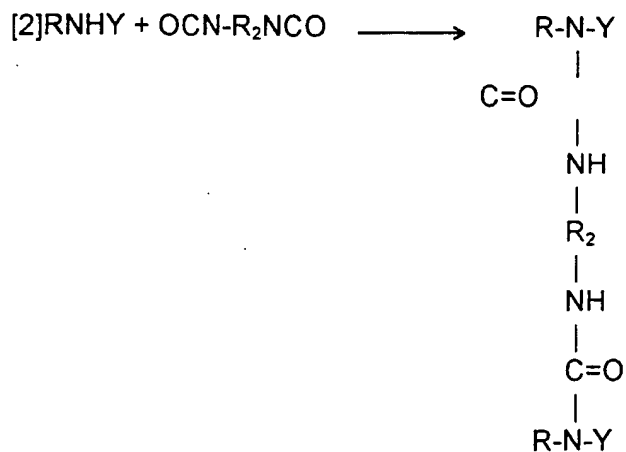
10 (3)

III.



15 Alkyl lactosylamine is coupled by reaction with a di-anhydride such as 1,2,4,5 benzene tetracarboxylic anhydride producing the gemini surfactant.

(4)



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Alkyl lactosylamine is coupled by reaction with a diisocyanate such as toluene diisocyanate or methylene bisdiphenyldiisocyanate.

Lactose is used as an example in the above descriptions, however, any  
5 reducing sugar can be substituted for lactose.

Lactose, and dodecylamine are the starting materials in the above reaction scheme.

Compounds of the invention can be prepared by coupling the sugar amine. The sugar amine is prepared by heating the sugar with amine in an alcohol-water  
10 mixture or dimethylformamide. Usually an excess of amine is used to suppress formation of tertiary amines. The main product usually crystallizes from the reaction mixture. Synthesis is described by O. Lockhoff (Angew. Chem. Int. Ed. Engl. 30, 1611-1620 (1991)).

The sugar amines can be coupled via numerous routes the most common  
15 being via bisacid chloride, dianhydride, diisocyanate and dihalide.

It has been reported that the secondary amine in single chain glycosylamines can react with acid chloride or acid anhydride selectively at low temperature.

Lactosylamine can be easily synthesized in either DMSO or methanol water  
20 solution. However, the lactosylamine synthesized in the presence of methanol and water usually retains a small amount of water even though it has been dried under vacuum. The presence of water in this instance could complicate certain reactions.

All the compounds were analyzed by thin layer chromatography (TLC) first in a different solvent system. The components of any sugar-containing compound were located by spraying the plates with dilute sulfuric acid (20% in ethanol), followed by heating. The sugar portion will react with sulfuric acid and become a black color after heating. The alkyl chain was detected by spraying a phosphomolybdic acid reagent (20% in ethanol) on the plate following the heating. Spots containing the alkyl groups gave a dark blue color. The compounds that contain the aromatic ring, the alkyl chains and sugars (Figures 4 and 5) were checked by UV light first and then by diluted sulfuric acid and phosphomolybdic acid reagents. UV active light prove the presence of the aromatic ring. The black color and the dark blue color indicate that the same spot also contains sugar portions and an alkyl chains. This TLC method indicated the compound contains all three portions.

Most intermediates and final compounds also were characterized by both  $^1\text{H}$ -NMR and  $^{13}\text{C}$ -NMR spectra (200 MHz and 50 MHz respectively). For the compounds with complicated structures such as II (Figure 4 and 5), special attention was paid to three chemical shift regions of both  $^1\text{H}$ -NMR and  $^{13}\text{C}$ -NMR. The proton NMR chemical shift in  $\delta 7.3 - 8.0$  indicated an aromatic portion,  $\delta 3.1 - 4.5$  indicated a sugar section and  $\delta 0.8 - 1.6$  indicated an alkyl region. The proton NMR of sugar gemini surfactants all have these three chemical shift regions with relatively accurate integration. These results can at least partially prove their chemical structure. Because these bulk molecules may not stay in the same plane and can possibly be twisted in three dimensions, the aromatic region may give multi peaks rather than single peak. This kind of structure was further

indicated by  $^{13}\text{C}$ -NMR. There are more than two aromatic peaks in the aromatic region ( $\delta 120 - 140$ ). The sugar region is in  $\delta 60 - 104$ . The peak at  $\delta 104$  is a very characteristic chemical shift for the ketyl group in lactose. The carbonyl group was found at around  $\delta 174$ , which indicated the two single lactosylamine chains are linked together. The alkyl chain region is between  $\delta 15 - 40$ . Even though some trace impurities appeared on NMR spectra due to the lack of a chromatographic purification step, overall, the NMR data agrees with the compounds' structures.

Since the surfactants of the invention exhibit an extremely low critical micelle concentration (cmc) as compared with conventional surface-active agents because of the presence of two hydrophobic moieties and two hydrophilic groups in their molecule, they are able to fully reduce surface tension, are highly soluble in water, and are extremely effective in aqueous solution at low concentrations. The surfactants of the invention can be used in any amount needed for the particular application and this can be easily determined by a skilled artisan without undue experimentation.

Whereas the surfactants of the invention can be used alone as the essential hydrotrope component, it has been unexpectedly found that blends of the compounds of the invention with certain conventional well known anionic, nonionic, cationic and amphoteric surfactants provide results beyond that expected and therefore synergistic that can be demonstrated in relation to critical micelle concentration and surface tension reducing ability.

Examples of the nonionic surfactants used herein include fatty acid glycerine esters, sorbitan fatty acid esters, sucrose fatty acid esters, polyglycerine

fatty acid esters, higher alcohol ethylene oxide adducts, single long chain polyoxyethylene alkyl ethers, polyoxyethylene alkyl allyl ethers, polyoxyethylene lanolin alcohol, polyoxyethylene fatty acid esters, polyoxyethylene glycerine fatty acid esters, polyoxyethylene propylene glycol fatty acid esters, polyoxyethylene sorbitol fatty acid esters, polyoxyethylene castor oil or hardened castor oil derivatives, polyoxyethylene lanolin derivatives, polyoxyethylene fatty acid amides, polyoxyethylene alkyl amines, an alkylpyrrolidone, glucamides, alkylpolyglucosides, mono- and dialkanol amides, a polyoxyethylene alcohol mono- or diamides and alkylamine oxides. Examples of the anionic surfactants used herein include fatty acid soaps, ether carboxylic acids and salts thereof, alkane sulfonate salts,  $\alpha$ -olefin sulfonate salts, sulfonate salts of higher fatty acid esters, higher alcohol sulfate ester salts, fatty alcohol ether sulfates salts, higher alcohol phosphate ester salts, fatty alcohol ether phosphate ester salts, condensates of higher fatty acids and amino acids, and collagen hydrolysate derivatives.

Examples of the cationic surfactants used herein include alkyltrimethylammonium salts, dialkyldimethylammonium salts, alkylmethylbenzylammonium salts, alkylpyridinium salts, alkylisoquinolinium salts, benzethonium chloride, and acylamino acid type cationic surfactants.

Examples of the amphoteric surfactants used herein include amino acid, betaine, sultaine, phosphobetaines, imidazoline type amphoteric surfactants, soybean phospholipid, and yolk lecithin.

Any of the commonly used auxiliary additives such as inorganic salts such as Glauber salt and common salt, builders, humectants, solubilizing agents, UV



absorbers, softeners, chelating agents, and viscosity modifiers may be added to the surfactants of the invention or blends thereof with other surfactants as disclosed herein.

The nonionic surfactants of the invention are extremely mild and non-irritating to both eyes and skin. They also exhibit enhanced wetting speed, greater surface tension reduction, high foaming and foam stabilization properties, low toxicity, and excellent compatibility with other anionic, cationic, and nonionic surfactants. The products of the invention are stable over a wide pH range and are biodegradable. These properties make these surfactants adaptable for use in products ranging from cosmetics to industrial applications and are usable wherever anionic surfactants have found use. These products are particularly useful for non-irritating shampoos, including baby shampoos, body shampoos including bubble baths, bar soaps, bath gels, hair conditioning gels, lotions, skin creams and lotions, make up removal creams and lotions, liquid detergents, dish detergents, and other washing and cosmetic products that contact the skin. The surfactants of the invention can also find use as hard surface cleaners including cars, dishes, toilets, floors, and the like; laundry detergents and soaps, metal working aids and the like.

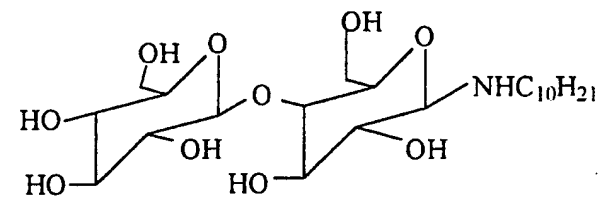
### **Experimental**

#### **Example 1**

##### **Preparation of N-decylactosylamine**

Lactose (34.5 g) was dissolved in dry dimethyl sulfoxide (770 mL) at 40-50°C. Decylamine (15 g) was added and the reaction was stirred at 50°C for 12 hours. A crude product precipitated from the reaction as white solid on the top of

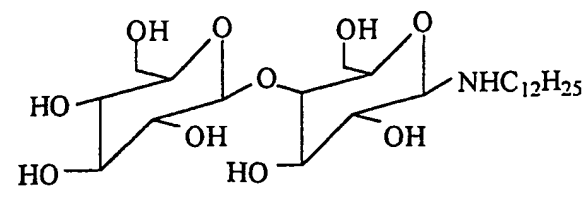
the solution. The reaction was then stopped by cooling to room temperature and the product was then isolated by filtration. The crude product was washed with cold ethanol several times to remove unreacted starting material. The product was then dried under vacuum and submitted for  $^1\text{H}$ -NMR and  $^{13}\text{C}$ -NMR spectral studies. NMR data agreed with the expected structure of final product (Figure 1). The product, a white solid, weighed 45 g.



## 10 Example 2

### Preparation of N-Dodecyl-lactosylamine

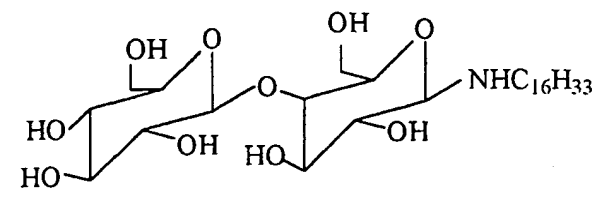
Lactose (34 g) was dissolved in a small amount of distilled water (60 mL) at 60°C. Dodecylamine (22.3 g) dissolved in methanol was added drop-by-drop to the water solution at 60°C as the reaction mixture was stirred vigorously. The reaction solution became cloudy at the beginning of the reaction and then became clear again after stirring for about 30 minutes. As the reaction continued, a white solid product began to accumulate on the top of the solution. The reaction was continued for three hours and was then stopped. White solid crude product was washed with acetone twice and dried under a vacuum. NMR spectra (Figure 2) agreed with the expected structure of the final compound. The yield of the reaction was about 75%.



### Example 3

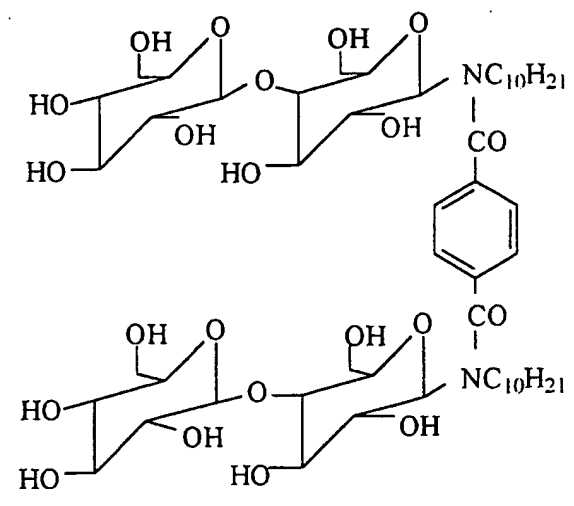
#### 5 Preparation of Hexadecyllactosylamine

Lactose (26 g) was dissolved in distilled water (60 mL) at 60°C. Hexadecylamine (25 g) dissolved in methanol was added to the water solution. The reaction solution became cloudy at the beginning of the reaction and then became clear again after stirring for 20 minutes. The reaction was continued for another three hours. A white solid product that was generated during the reaction accumulated on the top of reaction. The reaction was stopped by cooling to room temperature. The white solid product was collected by filtration and then washed with methanol and acetone. After drying under vacuum, the product was taken for NMR analysis. (See Figure 3). The result from NMR studies verified that this is the expected product.



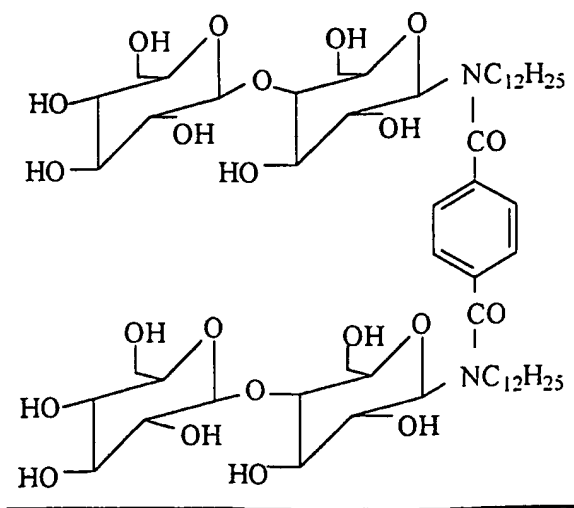
**Example 4****Preparation of Gemini Bis-decylactosylamide**

To decylactosylamine (5.6 g, 11.23 mmol) prepared in Example 1 dissolved in dry dimethylformamide is added a small amount of dimethylsulfoxide and triethylamine (0.5 mL) at 0°C. Terephthaloyl chloride (1.14g, 5.66 mmol) in dry dimethylformamide was added drop-wise to the solution as the solution was stirred vigorously. The reaction temperature was allowed to slowly warm to room temperature. After stirring for 17 hours, the reaction was gently heated at 60°C for a few hours until the thin layer chromatogram showed that all starting material had disappeared. The reaction was stopped by cooling to room temperature. The reaction solution was poured into water and then extracted with mixed solvent systems (chloroform and methanol) twice. After evaporating organic solvent, the solid crude product was dried under vacuum. Thin layer chromatography and NMR (Figure 4) all indicated this material is the expected product.



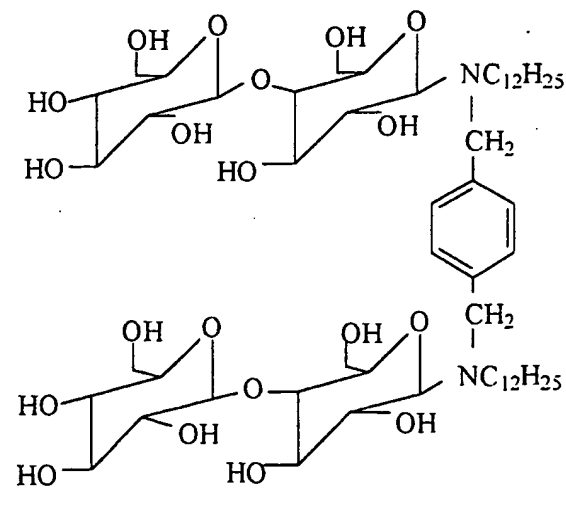
**Example 5****Preparation of Gemini Bis-dodecylactosylamide**

N-dodecylactosylamine (7.96g, 15.1mmol) was dissolved in dry dimethylformamide (DMF) in the presence of heat. Terephthaloyl chloride (1.5g, 7.39 mmol) dissolved in dimethylformamide and the excess amount of (1.8g) sodium carbonate were added to the solution at 0°C in an ice/water bath. The stirred reaction was gradually warmed to room temperature and then heated to 60°C for 20 hours. After thin layer chromatogram showed that most of the starting material had disappeared, the reaction was cooled to room temperature. The solid inorganic salt was filtered out. The organic layer was flushed with ether. A light yellow product was collected by filtration. The compound was washed twice with acetone, and then dried under vacuum. NMR data (<sup>1</sup>H-NMR and <sup>13</sup>C-NMR spectra are shown in Figure 5) agreed with the expected structure of the final compound. The yield of the final product was 4.6 g.



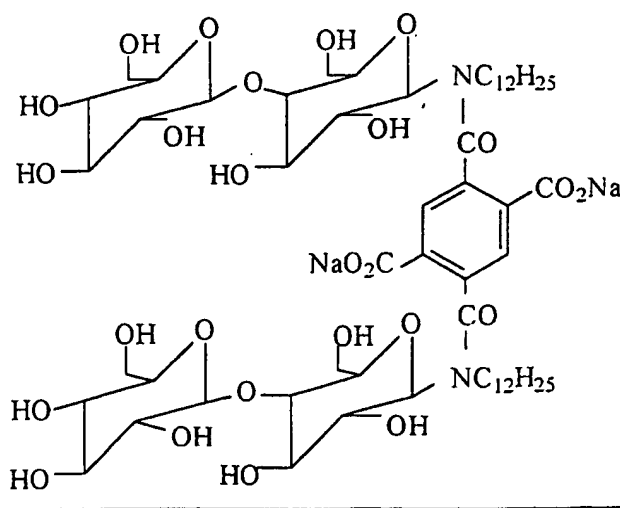
**Example 6****Preparation of Xylyl-Bis-dodecylactosylamide gemini surfactant**

N-dodecylactosylamine (8.0 g, 16.0 mmol) was dissolved in dry  
5 dimethylformamide in the presence of heat. Dibromo-p-xylene (1.900 g, 7.2 mmol)  
was dissolved in dimethylformamide and the excess amount of sodium carbonate  
were added to the solution at room temperature. The reaction was gently heated  
to 64°C and stirred for 15 hours. Thin layer chromatography showed that there  
was a new UV active sugar-containing product generated. The reaction was  
10 stopped by cooling to room temperature. Sodium carbonate salt was separated  
by filtration. A large amount of acetone was poured onto the organic layer and a  
white precipitate formed and was collected by filtration. This solid material was  
washed with cold ethanol twice. The final solid material was dried under vacuum.  
The yield of the reaction was about 40% and the NMR result agreed with the  
15 expected structure of the final product.



**Example 7****Preparation of 1,2,4,5-Benzenetetracarboxylic acid-derived bis-dodecylactosylamide gemini surfactant**

N-dodecylactosylamine (10.0 g, 20.0 mmol) was dissolved in dry dimethylformamide with heat added if necessary. 1,2,4,5-benzenetetracarboxylic anhydride (2.18 g, 10 mmol) and a small amount of sodium carbonate were added to the solution at room temperature. The reaction was stirred at 60°C overnight. The reaction was then stopped by cooling to room temperature. Thin layer chromatography indicated a new product was generated. The reaction was then diluted with acetone. Any insoluble inorganic material was separated by filtration and the organic layer was collected. After evaporating the solvent under reduced pressure, the solid product was washed twice with methanol and then collected. The material was dried under vacuum. The yield of the reaction was 60%, and the NMR result agreed with the expected structure of the final product.



**Example 8****Surface Activity**

The surfactants of the invention were measured for critical micelle concentration and surface tension reducing ability. The test methods utilized are described as follows:

**Critical Micelle Concentration (cmc)**

Aqueous solutions of the surfactants were prepared at varying concentrations. The surface tension at 20°C was measured by the Wilhelmy plate method and plotted vs. the logarithm of the concentration. The critical micelle concentration (cmc) was determined as the value at which the slope of the line of the graph changed abruptly.

The surface tension reducing ability was determined from the surface tension at the critical micelle concentration.

Surface tension measurements were made for each of the surfactants prepared from examples 1 and 2 using a Kruss K-12 tensiometer (plate method). The appropriate values were determined as follows:

$$\rho = \frac{d\gamma}{d\log C_r} / 2.303RT$$

where

- $\rho$  = surface excess concentration (mol/cm<sup>2</sup>)
- $d\gamma$  = change in surface or interfacial tension of the solvent (dyn•cm<sup>-1</sup>)
- $R$  = 8.31x10<sup>7</sup> erg mol<sup>-1</sup> • K<sup>-1</sup>
- $C$  = molar concentration of solution



T = absolute temperature (°K)

pC-20 at the solution/air interface is defined as the negative  $\log$  of the surfactant concentration required to lower surface tension by 20 dyne/cm.

The results obtained for the surfactants alone are reported in Table 1.

5

#### Ross Miles Foam Height

The product was evaluated as a foaming agent using the Ross Miles Foam Height Test as outlined in ASTM method D1173. The foam was evaluated and the results were recorded.

10

**TABLE I**

Surfactant	cmc (wt. %)	Surface Tension dyne/cm	Ross Miles Foam Height (mm)
Example 4	$1.9 \times 10^{-4}$	32.0	1655-146
Example 5	$6 \times 10^{-4}$	29.2	1555-145
C <sub>12.5</sub> H Glycoside	$4 \times 10^{-3}$		

As can be seen from the respective derived values, the surfactants afford superior foaming characteristics and enhanced surface tension reduction properties.

When the surface properties for the amphoteric geminini surfactant compounds of the were compared to the corresponding conventional amphoteric

surfactants, the novel compounds of the invention showed two o unexpected surface active properties; unusually low critical micelle concentratioion (cmc) and  $pC_{20}$  values in aqueous media. These properties are a measure of ff the tendency of the surfactant to form micelles and adsorb at the interface, and consequently, to  
5 reduce surface tension respectively.

This unusually high surface activity for these molecules is a r result of their unique structure; the presence of two optimally spaced hydrophobioic chains and hydrophilic groups.

This molecular structure provides energetically favorable decrcrases in the  
10 free energy of adsorption and micellization through favorable distorbrtion of water structure, and, at the same time, providing a "close packed" arrangement at the interface. This is reflected by their relatively low area per molecule that is unexpected from the molecular dimensions for the molecule. TtThe area per molecule for the compounds of the invention are comparable to cccorresponding  
15 conventional surfactants. The ability of the compounds of the inventintion to distort water structure through inhibition of crystalline or liquid crystalline phanase formation in bulk phase and at the same time to pack closely on adsorption at it the interface is contrary to conventional wisdom. This again demonstrates the uruniqueness of the molecular design for these compounds which is very critical il to providing  
20 unexpected exceptional surface and performance properties.

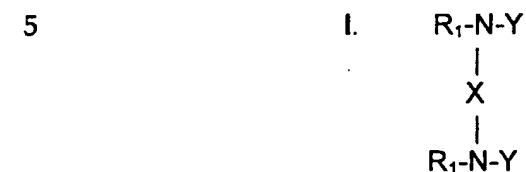
Exceptional surface activity and unique structural featutres for the compounds of the invention provide two other important performanonce properties that can have immense practical application in industry, i.e., their h:hydrotropicity, which is the ability of organic substances to increase the solubibility of other

insoluble organic substances in water, and solubilization, the dissolving of water insoluble organic compounds into aqueous surfactant solutions above their cmc levels. The compounds of the invention, because of their very low cmc values, are efficient solubilizers. This latter property will not only allow the formulation of  
5 homogeneous water insoluble materials, but also will enhance the surface activity of other surfactants whose low water solubility restrict their use. These novel surfactants of the invention are far better than comparable conventional surfactants in hydrotroping and solubilizing properties.

Because of their unusually high surface activity, coupled with their  
10 hydrotropicity and solubilization properties, compounds of this invention will provide exceptionally high performance properties, at very low concentration, in practical applications such as detergency emulsification, solubilization, dispersancy, hydrotropicity, foaming and wetting. In addition, due to their extremely low monomer concentration at use levels, because of their extremely  
15 low cmc values, use of lower concentration of the compounds of the invention than conventional surfactants can provide extremely low or no irritancy in personal care applications.

### What we claim is:

- 1) A gemini surfactant composition comprising the structural formula:



10 wherein R and R<sub>1</sub> independently represent the same or different linear, branched, saturated or unsaturated hydrocarbyl moieties with a carbon chain length of from about C<sub>6</sub>-C<sub>23</sub> and wherein Y and Y<sub>1</sub> independently represent the same or different alcohol-containing moieties having at least  
15 two and preferably more hydroxyl groups with the further stipulation that one but not both may be hydrogen and X independently represents R<sub>2</sub> or -COR<sub>2</sub>CO- wherein R<sub>2</sub> represents a C<sub>1</sub> to C<sub>20</sub> straight or branched chain alkyl, aryl, carboxyaryl, alkylaryl, dicarboxyaryl or diaminoalkyl.

- 2) The surfactant composition of claim 1 wherein R and R<sub>1</sub> ir independently  
20 represent a straight or branched alkyl group of from about 6 to 12 carbon  
atoms.
- 3) The surfactant composition of claim 2 wherein Y and Y<sub>1</sub> ir independently  
represent an alcohol-containing moiety selected from the group consisting  
essentially of monosaccharides, disaccharides, polysaccharides s and mixtures  
25 thereof.
- 4) The surfactant composition of claim 3 wherein said monosacaccharides are  
selected from the group consisting essentially of glyceraldehydyde, erythrose,

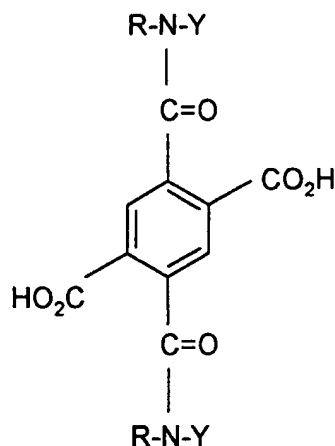
threose, ribose, arabinose, xylose, fructose, lyxose, allose, altrtrose, glucose, mannose, gulose, idose, galactose, talose and mixtures thereof.

- 5) The surfactant composition of Claim 3, wherein said dissacharidide is selected from the group consisting essentially of lactose, maltose, sucrosøse, cellobiose, gentibiose and mixtures thereof.
- 6) The surfactant composition of Claim 3, wherein said polysaccharitide is selected from the group consisting essentially of amylose, amylopectin, ti trehalose and mixtures thereof.
- 7) A surfactant composition of Claim 5, wherein X is a straight or brøranchèd chain C<sub>6</sub> to C<sub>15</sub> alkyl, aryl, alkylaryl and mixtures thereof.
- 8) The gemini surfactant of claim 1 comprising the structural formulala:



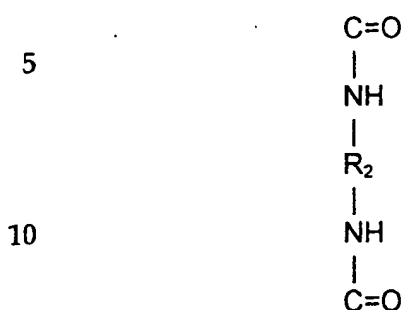
wherein R<sub>2</sub> represents a straight or branched chain alkyl, aryl or or alkyl aryl and R, R<sub>1</sub> and Y have been hereinbefore defined.

- 9) The gemini surfactant of claim 1 comprising the general formula: a:



wherein R, R<sub>1</sub>, and Y have been hereinbefore defined.

- 10) A gemini surfactant of claim 1 comprising the general formula:



wherein R<sub>2</sub> has been hereinbefore defined.

- 11) A surfactant composition of Claim 5, further comprising a surfactant selected from the group consisting of an anionic, nonionic, cationic, and amphoteric surfactant.
- 12) The surfactant composition of Claim 11, wherein said nonionic surfactant is selected from the group consisting of a fatty acid glycerine ester, a sorbitan fatty acid ester, a sucrose fatty acid ester, a polyglycerine fatty acid ester, a higher alcohol ethylene oxide adduct, a single long chain polyoxyethylene alkyl ether, a polyoxyethylene alkyl allyl ether, a polyoxyethylene lanolin alcohol, a polyoxyethylene fatty acid ester, a polyoxyethylene glycerine fatty acid, a

polyoxyethylene propylene glycol fatty acid ester, a polyoxyethylene sorbitol fatty acid ester, a polyoxyethylene castor oil or hardened castor oil derivative, a polyoxyethylene lanolin derivative, a polyoxyethylene fatty acid amide, a polyoxyethylene alkyl amine, an alkyl pyrrolidone, glucamides, alkylpolyglucosides, a mono- or dialkanol amide, a polyoxyethylene alcohol, mono- or diamide, an alkylamine oxide, and mixtures thereof.

13) The blend of surfactants of Claim 11, wherein said anionic surfactant is selected from the group consisting of a fatty acid soap, an ether carboxylic acid or its salt thereof, an alkane sulfonate salt, an  $\alpha$ -olefin sulfonate salt, a sulfonate salt of a higher fatty acid ester, a higher alcohol sulfate ester salt, fatty alcohol ether sulfate salts, a higher alcohol phosphate ester salt, a fatty alcohol ether phosphate ester salt, a condensate of higher fatty acids and amino acids, and a collagen hydrolysate derivative.

14) The blend of surfactants of Claim 11, wherein said cationic surfactant is selected from the group consisting of an alkyltrimethylammonium salt, a dialkyldimethylammonium salt, an alkyl dimethylbenzylammonium salt, an alkylpyridinium salt, an alkylisoquinolinium salt, benzethonium chloride, and an acylamino acid type cationic surfactant.

15) The blend of surfactants of Claim 11, wherein said amphoteric surfactant is selected from the group consisting of amino acids, betaines, sultaines, phosphobetaines, imidazoline-type amphoteric surfactants, soybean phospholipid, and yolk lecithin.

16) A cleaning composition comprising an aqueous solution having a cleaningly effective amount of the composition of Claim 1 dissolved therein.

- 17) The cleaning composition of claim 16, wherein the solution is selected from the group consisting of hair shampoos, baby shampoos, body shampoos, bubble baths, bar soaps, bath gels, hair conditioning gels, skin creams and lotions, skin contacting cosmetics, make up removal creams and lotions, liquid  
5 detergents, dish detergents, liquid soaps, bleach activators, bleach stabilizers and the like.
- 18) A method for the preparation of a novel gemini surfactant containing two hydrophilic and two hydrophobic chains connected by a carbon-nyl containing bridge wherein said hydrophilic chains are comprised of the same or  
10 different sugar moieties, said method comprising:
- a) aminating said sugar moiety with an amine comprising a C<sub>6</sub>-C<sub>23</sub> straight, branched, substituted or unsubstituted alkyl, aryl or alkylaryl in the presence of DMSO<sub>4</sub> at elevated temperature and
- b) condensing two of said aminated sugar moieties in the  
15 presence of phthaloyl chloride.
- 19) The method of claim 18 wherein said sugar moiety is selected from the group consisting essentially of monosaccharides, disaccharides, polysaccharides, and mixtures thereof.
- 20) The method of claim 19 wherein said monosaccharide is selected from the  
20 group consisting essentially of glyceraldehyde, erythrose, threose, ribose, arabinose, xylose, fructose, lyxose, allose, altrose, glucose, mannose, gulose, idose, galactose, talose and mixtures thereof.



- 21) The method of claim 20 wherein said disaccharide is selected from the group consisting essentially of lactose, maltose, sucrose, cellobiose, gentibiose and mixtures thereof.
- 22) The method of claim 21 wherein said polysaccharide is selected from the group consisting essentially of amylose, amylopectin, trehalose and mixtures thereof.
- 5

# INTERNATIONAL SEARCH REPORT

Int'l Application No No

PCT/US 98/06970 '0

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 C07H15/12 C11D1/52

According to International Patent Classification(IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 C07H C11D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 95 19951 A (PROCTER & GAMBLE) 27 July 1995 see the whole document, but especially claims 1,4,6,9,10; examples III,IV,VI,VII ---	1-2-22
Y	EP 0 688 781 A (KODAK LTD ;EASTMAN KODAK CO (US)) 27 December 1995 see claims 1-9,13 ---	1-2-22
Y	WO 95 19955 A (PROCTER & GAMBLE) 27 July 1995 see claims 1-7 ---	1-2-22
Y	WO 95 19953 A (PROCTER & GAMBLE) 27 July 1995 see claims 1-7 ---	1-2-22
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Date of the actual completion of the international search

17 September 1998

Date of mailing of the international search report 1

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 5 534 197 A (SCHEIBEL JEFFREY J ET AL) 9 July 1996 see claims 1-9 ---	1-1-22
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A	F.M.MENGER ET AL.: "Gemini Surfactants : A New Class of Self-Assembling Molecules." JOURNAL OF THE AMERICAN CHEMICAL SOCIETY., vol. 115, 1993, pages 10083-10090, XP002028461 DC US cited in the application see the whole document -----	1 1

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Information on patent family members

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information on patent family members

International Application No No

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